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STUDIES ON NEARCTIC *EUCHLOE*. PART 6. SYSTEMATICS OF ADULTS

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This paper presents a discussion of some external morphological features of the adults of Nearctic *Euchloe*, a key to identification, descriptions of named entities, and illustrations. Stress will be given those features found most useful in the separation of adults.

METHODS

CHROMATOGRAPHY. The procedures followed were based on those of Hadorn and Mitchell (1951) and Biserte (1960). Solvent systems of n-Propanol and aqueous ammonia (2:1) and Butanol, glacial Acetic acid, and water (4:1:5) were employed. The chromatograms were obtained by a uni-directional ascending method and the spots were revealed under ultra-violet illumination.

EXTERNAL FEATURES. With the exception of androconial scales, all external features were studied with the aid of a dissecting microscope at 10, 30, or 60 power.

Measurements of wing length were made with a vernier caliper to the nearest one-tenth millimeter. Measurement of costal length was made from the point of wing attachment to furthest extent of the apex, not including the fringe.

The width of the black bar at the end of the cell on the dorsal surface of the forewing was measured by counting the number of scale rows on the right wing under 30 power from the first row with 50% or more black scales to the first comparable row on the opposite side. The number of white scales in the bar were

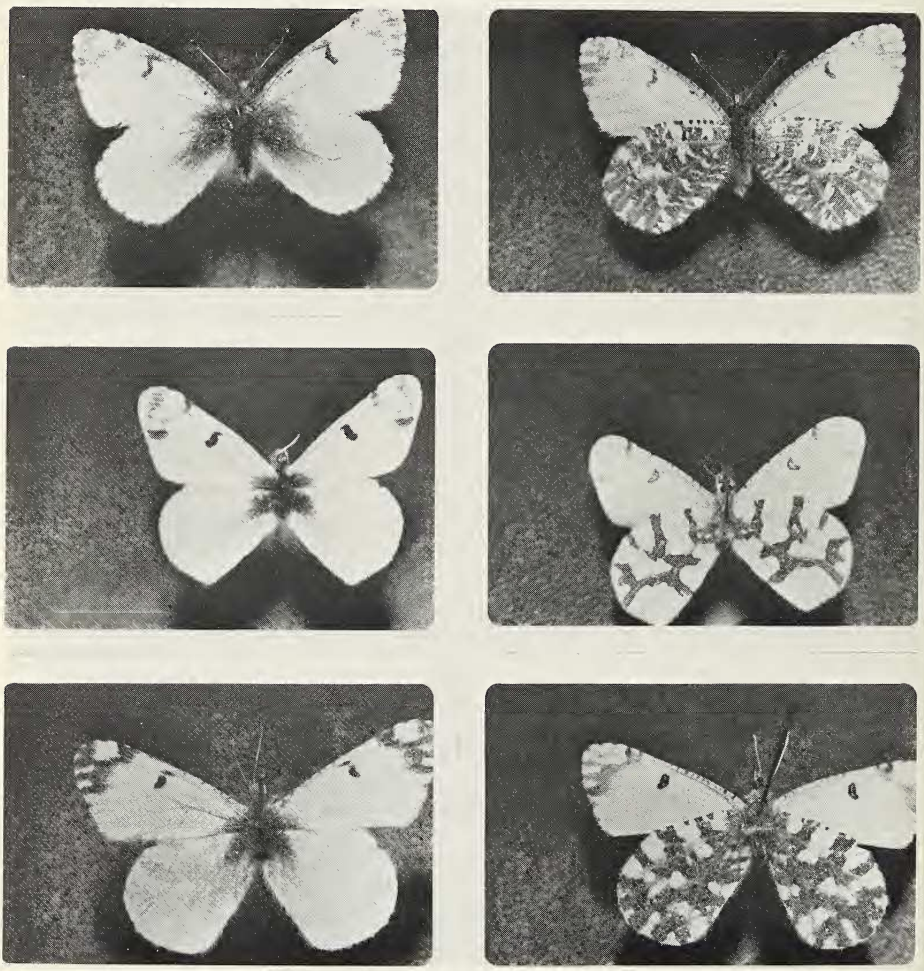

Fig. 1. Upper Row. Left: *Euchloe creusa,* male, upper surface; Right: *Euchloe creusa,* male lower surface; Middle Row. Left: *Euchloe olympia,* male, lower surface; Lower Row. Left: *E. ausonides,* male, upper surface; Left: *E. ausonides,* male, lower surface.

counted below the costal vein, as the bar is frequently ill-defined above this vein. Any white scale completely surrounded by black scales was considered as occurring within the bar. For individuals with more than fifty white scales in the bar, a portion of the bar was counted for the character, and the total was then arrived at by extrapolation.

The relative length of the radial veins were compared with the aid of an ocular grid. If one does not clear the wings, the veins are best observed on the ventral surface of the forewing with light from the illuminator striking the wing at an oblique angle.

Androconial scales were studied by scraping the area of the bar on the dorsal surface of the forewing with an insect pin or dissecting needle, transferring the scales to a microscope slide, covering them with a cover slip, searching for the proper scales under low power, and finally studying them under 200 to 400 power with a compound microscope. For permanent preparations, a mounting medium should be applied around the edge of the cover slip only, and pressure applied to the cover slip until the preparation dries.

GENITALIC PREPARATIONS. The genitalia were subjected to the usual preparatory procedures but were not mounted on slides. Genitalia were observed in a mixture of ethanol and glycerine in a small dissecting dish and were stored in small vials inside larger museum jars.

DRAWINGS. The subjects for the figures were observed through a binocular microscope equipped with an ocular grid. Pencil drawings were made on grid paper, and later the originals were traced onto finer grade paper and inked in.

MORPHOLOGICAL FEATURES

PIGMENTATION. It is well known that a group of pigmental compounds known as pterines is responsible for the white, yellow, and red wing colors of many members of the family Pieridae. Since these compounds have been demonstrated to occur in the wings of a species of *Anthocaris* by Good and Johnson (1949), and since the *Euchloe* possess white and yellow wing pigments, I decided to demonstrate the presence of pterines in the wings of *Euchloe.*[1] Specimens of *Euchloe ausonides* and *E. hyantis lotta,* as well as other species of Pieridae, were used in the experiment. Light blue fluorescent spots with RF

[1] Chromatography experiment conducted in insect physiology laboratory at San Jose State College, Dr. Ballard, instructor.

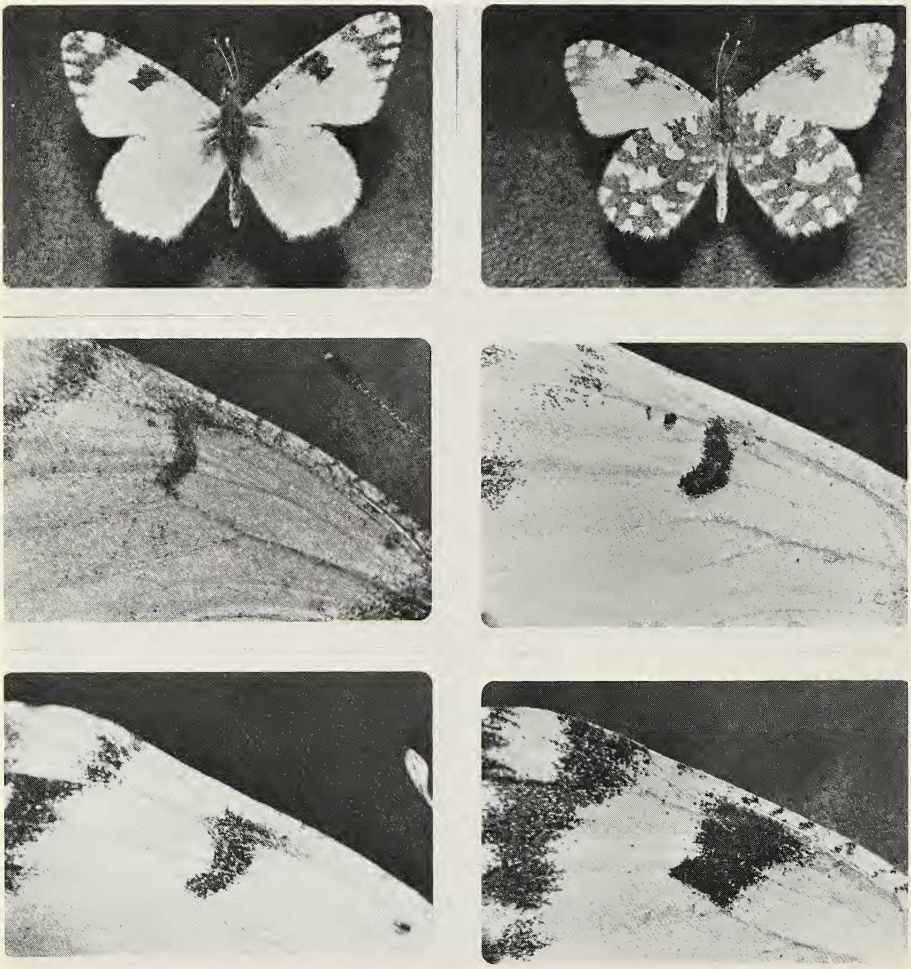

Fig. 2. Upper Row. Left: *Euchloe hyantis,* male, upper surface; Right: *E. hyantis,* male, lower surface; Middle Row. Left: *E. creusa,* male, right forewing; Right: *E. olympia,* male, right forewing; Lower Row. Left: *E. ausonides,* male, right forewing; Right: *E. hyantis,* male, right forewing.

values of 0.21 were obtained for both species of *Euchloe* with the propenol-ammonia solvent system. Since this finding was also produced with a wing sample of *Pieris rapae* L. it was tentatively assumed that leucopterin, the pigment responsible for the white wing color of many Pieridae, was the compound which formed these spots. Light blue fluorescent spots with RF values of 0.35 and barely discernable purple fluorescent spots with RF values of 0.29 were obtained for both species with the butanol-acetate-water solvent system. It was deduced that these values possibly represented breakdown products of xanthopterin, the pigment responsible for the yellow wing colors of many Pieridae. Needless to say, these results are far from definitive. It was realized that either larger samples or more refined techniques should be used in conjunction with chemically defined standards if significant differences are to be shown between species or populations of *Euchloe.*

The differences between species, populations, and individuals with regard to the whitness of wing color may be due to the presence of varying proportions of xanthopterin mixed with leucopterin. The pearly lustre or sheen or its absence are best explained by physical effects, i.e., the presence of ridges on the scales, the angle of scale elevation from the point of attachment, thickness of scales.

SCALE TYPES. The "marbling" on the ventral surface of the hindwings is composed of two types of scales. The first type, which consists of the white and yellow scales, is of roughly rectangular outline with lobes or teeth on the distal margin. There appear to be differences in the number and outline of the lobes or teeth between different populations or entities of *Euchloe.* However, a satisfactory method of noting these differences was not arrived at in the course of this study. The black scales on the ventral surface of the hindwing, which together with the yellow scales give the visual effect of green "marbling", are ovoid in outline and are dentate on the distal margin with the exception of many individuals of *Euchloe ausonides coloradensis.* The distal margin of the black scales of these individuals is simple.

The males possess androconial scales on the dorsal surface of the forewings in the area of the black bar marking located at the distal margin of the discal cell. The location of these

TABLE 1. STATISTICAL SURVEY OF SOME WING CHARACTERS

	FOREWING[1]			BAR WIDTH[2]			SCALE NUMBER[3]		
	$\bar{X}$	$S_{\bar{x}}$	N	$\bar{X}$	$S_{\bar{x}}$	N	$\bar{X}$	$S_{\bar{x}}$	N
Euchloe ausonides	19.9	.12	158	11.7	.25	160	81.0	3.57	158
	20.4	.18	72	15.2	.46	62	52.8	6.50	58
Euchloe a. coloradensis	19.5	.03	35	10.8	.54	44	72.9	7.00	44
	18.7	.62	6	13.9	.81	8	50.6	7.22	8
Euchloe a. mayi	19.6	-	1	8.1	.67	10	103.0	20.03	10
	-	-	-	11.0	2.00	3	78.3	30.81	3
Euchloe creusa	17.4	.18	19	9.9	.64	18	9.9	1.86	18
	17.7	.36	5	10.5	1.35	4	1.5	1.06	2
Euchloe hyantis	17.7	1.80	39	12.9	.26	49	.2	.06	49
	18.8	.26	15	15.5	.65	15	.4	.13	16
Euchloe hyantis lotta	17.8	.15	83	20.4	.88	94	.1	.02	95
	17.9	.17	52	23.7	1.46	50	.2	.06	52
Euchloe hyantis andrewsi	18.5	.24	5	13.0	.60	8	6.0	1.99	8
	-	-	-	18.0	-	1	4.0	-	1

scales has never been reported for members of the tribe Euchloini. Warren (1961) and Chang (1963) have reported that the androconial scales have a distinctive shape which is constant for any given species of the genus *Pieris*. It was hoped that these scales would furnish similar diacritical differences in the Nearctic *Euchloe*, but upon microscopic examination they were found to show very slight interspecific differences. While the androconial scales of the Ausonides species group were relatively constant in having the lateral edges of the scales approximately parallel or slightly divergent, the androconial scales of the Hyantis complex were found to be quite variable. On more than one occasion scales varying from ovoid to trapezoidal were found on one specimen of *Euchloe hyantis lotta*.

BAR CHARACTERS. Since Brown (1955) reported that *Euchloe hyantis lotta* can be distinguished from *E. ausonides coloradensis* by its wider bar marking, it was decided early in the study to use this as a possible character in the study. The bar marking was measured by counting its width at a point near the middle in scale rows, i.e. the number of scales encountered in a line across the marking. All specimens recorded in the study were coded for this character. It was found that although individual variation was wide it did give a good measure of difference between certain entities (see Table 1).

In looking at specimens with intent to code for the above character, it was discovered that all specimens of *E. ausonides* possessed a scattering of white scales within the bar, while inividuals of *E. hyantis* did not. Hence, the writer coded all specimens for the number of white scales in the bar marking. This character appears to be the best qualitative means of separating adults of *Euchloe ausonides* from *Euchloe hyantis* without resorting to dissection of the genitalia. Occasionally worn individuals of *E. ausonides*, especially females, will not display this character well as the scales appear to be more deciduous with age than are the other scales on the wings. Some populations of *Euchloe hyantis* that occur in the middle elevations of the Sierra Nevada of California are composed of individuals which so closely resemble *E. ausonides* from nearby areas that only by examining the individuals in question under a binocular microscope for this character can one be sure which species he is dealing with. The genitalia of such individuals subsequently support the conclusions which were arrived at on the basis of the presence or absence of white scales in the bar

marking. When other evidence, which will be presented in later papers of this series, indicates that *Euchloe hyantis* must have become isolated from the line which gave rise to the radiation of the Ausonides species group at a relatively early date, one must realize that this is either a startling example of convergent evolution or an improbable coincidence.

VENATION. In the past, several workers, including Dyar (1894) and Grote (1900), have proposed that members of the genus *Euchloe* can be discriminated on the basis of wing venation, while other writers such as Butler (1899) and Klots (1930a) have argued against the wisdom of employing this character. The radial veins on the forewing were usually used in attempts to utilize wing venation as a classificatory aid for *Euchloe.* The antagonists to such hypotheses reasoned that these characteristics were variable from one specimen to another. The present writer found that although the state of the radial veins varied slightly from one individual to another, definite trends for each species were clearly discernible. (see Fig. 4). The method employed was to contrast the length of the stem of the fourth and fifth radial veins from the bifurcation of the third radial with the length of the fourth radial vein. A trend for *Euchloe creusa* could not be noted owing to the small sample that was available, however specific characteristics were found for the other three species. The fourth radial of *Euchloe olympia* was invariably longer than its stem, the length of the fourth radial of *E. ausonides* was shorter or about equal to the length of its stem, and the fourth radial of individuals of *Euchloe hyantis* was always shorter than its stem. In fact, the fourth radial vein of both wings of many individuals of *E. hyantis* was found to be absent or only barely present.

EXTERNAL GENITALIA. An excellent world-wide tribal revision of the Euchloini by Klots (1930a) was based in large part on the structure of the external genitalia of the male insects. In spite of that fact, no satisfactory genitalic characteristics have been reported at the species level for any of the Nearctic *Euchloe.* As with many other characteristics of this subgenus, the external genitalia are perplexingly similar in superficial appearance. As a result of the study reported in this paper several features of the genitalia were found which will readily separate individuals of the two species groups involved. The outline of the juxta, when viewed from the posterior angle, is V-shaped for individuals of *Euchloe ausonides*

and is Y-shaped for the other three species (see Fig. 3). For species of the Ausonides group, the lateral edges of the tegumen, when viewed from the dorsal aspect, are parallel and do not converge until just prior to the point of juncture with the uncus, while for individuals of the Hyantis complex, the lateral edges of the tegumen are noticeably convergent distally or are irregular. The saccus of members of the Ausonides group tends to be regular in outline, while the saccus of individuals of the Hyantis complex is irregular in outline. The cucullus of members of the Hyantis complex terminates abruptly after the elaboration of the distal tooth, while the cucullus area of the valvae of members of the Ausonides group extends a short distance beyond the distal tooth (Fig. 3).

KEY TO THE ADULTS OF NEARCTIC *EUCHLOE*

1. Length of R_4 much less than length of stem $R_{4\ 5}$, white ground on ventral surface of hindwing usually with pearly lustre, bar at end of cell on dorsal surface of forewing containing less than five white scales below costal vein, cucullus area of valvae terminating abruptly after distal tooth, lateral margins of uncus becoming convergent distally (dorsal view) ..... *Euchloe hyantis* complex 7
Length of R_4 about equal to or greater than length of stem $R_{4\ 5}$, white ground on ventral surface of hindwing usually dull white, bar at end of cell on dorsal surface of forewing containing five or more white scales below costal vein, cucullus area of valvae not terminating abruptly after distal tooth, lateral margins of uncus parallel or only slightly convergent distally ..... Ausonides species group 2

2(1). Juxta of male V-shaped, sterigma usually evenly curved in lateral or ventral view, female sometimes with dorsal surface of hindwing distinctly yellowish in color in comparison to ground of forewing .. 3
Juxta of male Y-shaped, sterigma sinuous in lateral of ventral view, ground color of dorsal surface of hindwing almost never yellowish....6

3(2). Bar at end of cell on dorsal surface of forewing narrow, black scales on ventral surface of hindwing often ovoid in outline, a higher percentage of black scales as compared to yellow scales on ventral surface of hindwing, southern Rocky Mountains of northern New Mexico, Colorado, and southern Wyoming, often at high altitudes .....*Euchloe ausonides coloradensis*
Bar at end of cell narrow or wide, black scales on ventral surface of hindwing with two or more teeth or lobes distally, black scales and yellow scales in about equal numbers on ventral surface of hindwing, not occurring in the areas listed above 4

4(3). Bar narrow, hindwing of female barely contrasting in color with forewing, low mountains of west-central Manitoba ..... *Euchloe ausonides mayi*
Bar wide, usually more than eleven scale rows in width, hindwing ground of female usually contrasting with that of dorsal surface of forewing, not occurring in west-central Manitoba. 5

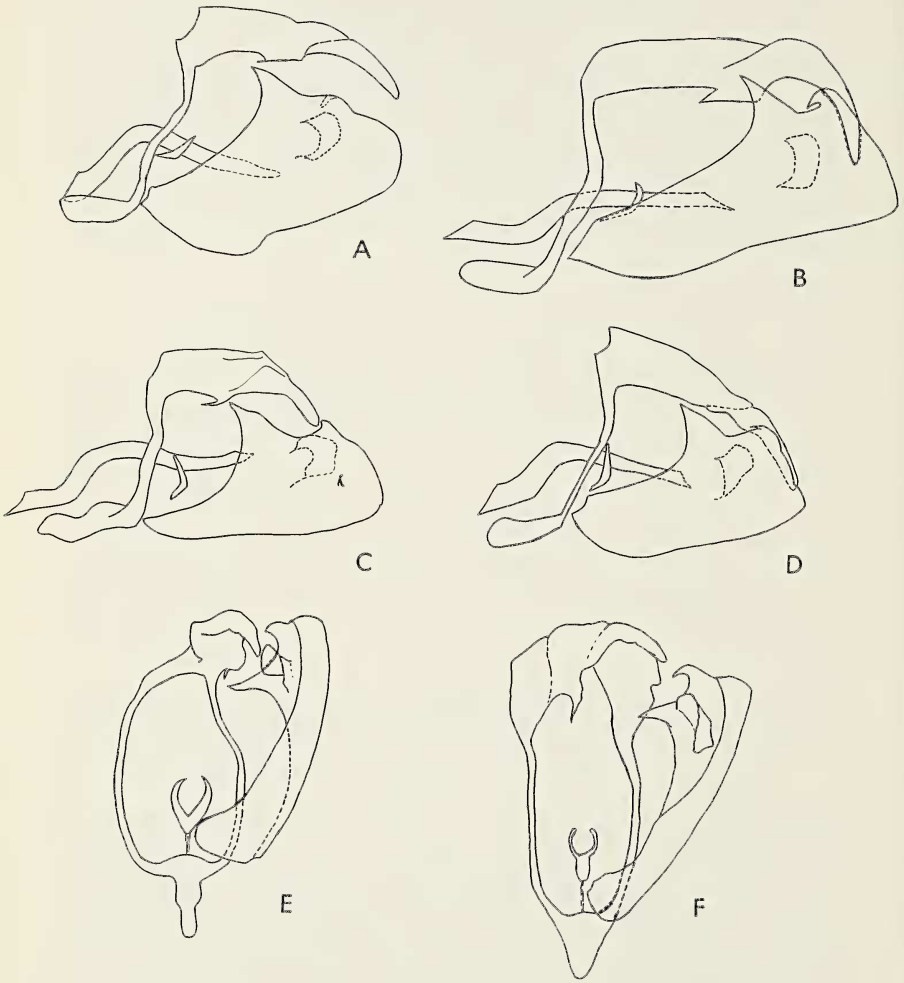

Fig. 3. Lateral view of male genitalia. A. *E. creusa.* B. *E. olympia.* C. *E. ausonides.* D. *E. hyantis.* E-F. Posterior view of male genitalia showing two configurations of juxta.

5(4). Female possessing one of three phenotypes, i.e. both wings white dorsally, both yellow, or forewing white and hindwing yellowish, occuring in the Coast Range, Sacramento Valley, and northern San Joaquin Valley in California from Mendocino County south to Monterey County ..... *Euchloe ausonides ausonides*
Female with dorsal surface of hindwing always distinctly yellowish, not in the lowlands of central California, southern Rocky Mountains, or west-central Manitoba ..... *Euchloe ausonides* ssp.

6(2). Antennae clothed with white scales only, marbling on ventral surface of hindwing strongly reduced, black marking on apex of forewing often reduced, buff-colored scaling usually not present on costal margin of forewing, black scaling not invasive on dorsal surface of hindwing, occurring in eastern half of United States and adjacent portions of Canada in Manitoba and Ontario ..... *Euchloe olympia*
Antennae clothed with both white and black scales, marbling on ventral surface of hindwing often heavy and of a "broken" nature, black marking on apex of forewing not reduced, buff-colored scaling present on costal margin of forewing, black scaling at base of hindwing on dorsal surface invasive outwardly more so than other species or Nearctic *Euchloe*, occurrence associated with mountain cordillera of Canada and Alaska ,occurring near timberline, *i.e.* 7000' in southern Alberta, 4000' in northern British Columbia and close to sea level in Northwest Territories (McKenzie River delta) ..... *Euchloe creusa*

7(1). Occurrence associated with Northern Desert Scrub (sagebrush) or Southern Desert Scrub Biomes (desert) west of the Continental Divide (except Rio Arriba County, New Mexico) and east of the Sierra Nevada and Cascade Mountains ..... *Euchloe hyantis lotta*
Occurrence in the north Coast Range of California, west slope of the Sierra Nevada, Transverse Ranges of southern California (excluding lower desert slopes), and the Peninsular Ranges of San Diego County, California and Baja California del Norte 8

8(7). Occurring in the north Coast Range of California from Sonoma County north to Siskiyou County ..... *Euchloe hyantis hyantis*
Not occurring in the north Coast Range of California 9

9(8). Occurring in the higher portions of the San Bernardino Mountains ..... *Euchloe hyantis andrewsi*
Not occurring in the higher portions of the San Bernardino Mountains of southern California ..... *Euchloe hyantis* ssp.

Euchloe ausonides (Lucas)

Male. — Forewing length, 21 mm. Antennae: brownish-tan, outer surface of shaft clothed with black and white scales, black predominating, nudum and inner surface of shaft naked, tip of nudum with small microtrichia; labial palpi twice as long as head, directed anteriorally at a slight dorsal angle, clothed with black and white elongate scales, about three and a half times as long as wide, long white hair-like scales on inner face, similar black scales directed ventrally, a group of longer scales, both white and black, projecting from ventral base of palpi; head

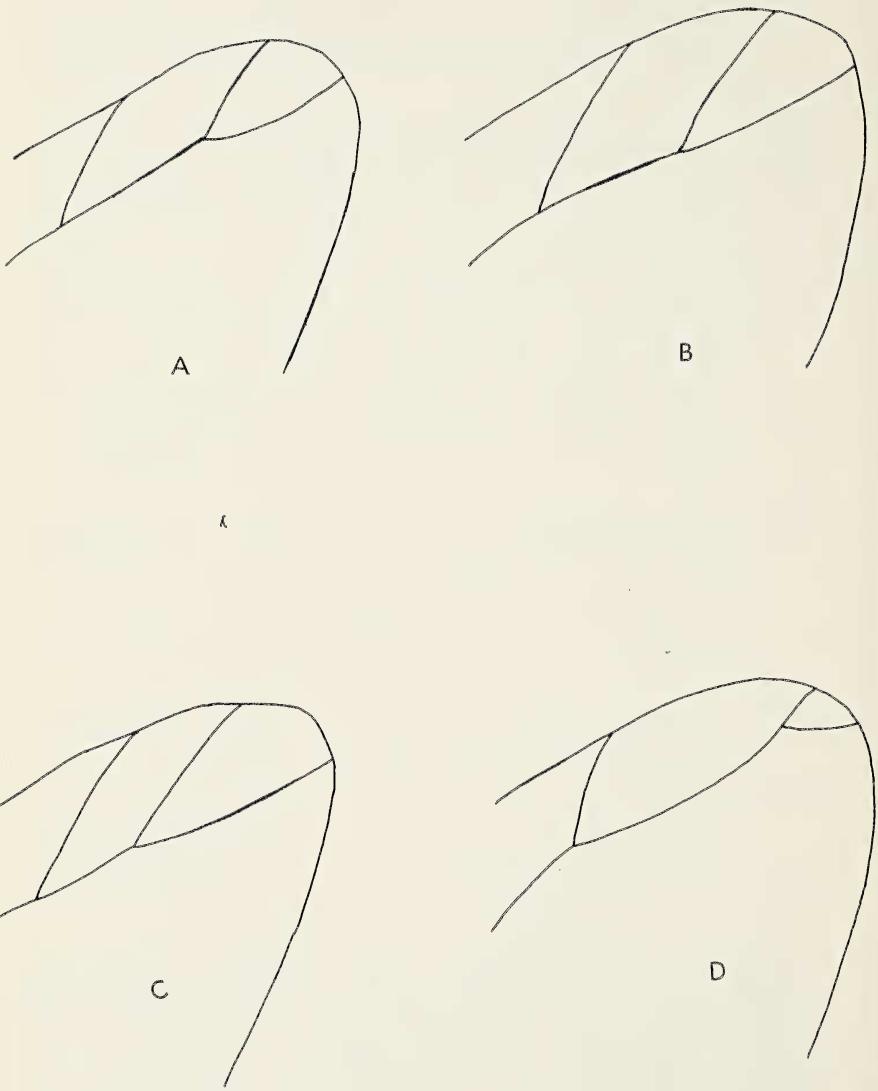

Fig. 4. Venational configuration of radial group of right forewing. A. *E. ausonides*. B. *E. creusa*. C. *E. olympia*. D. *E. hyantis*.

black with eyes green, frons with prominent tuft of long black, white, and yellowish hair-like scales, primarily white ventrally and yellowish laterally; vertex with long white hair-like scales, a patch of yellow and black hair-like scales half the length of those on center of vertex present on lateral margins of vertex, a group of shorter bright yellow scales between eyes and base of antennae; eyes bordered dorso-posteriorally by bright yellow and black flattened scales, a collar of bright yellow hair-like scales on cervical region adjacent to posterior and ventral margin of eyes.

Thorax: clothed with black appressed quadrate flattened scales and long hair-like scales, whitish-gray throughout 9/10 of length and black at base; pleuron covered with yellow sub-elliptic flattened scales and long yellowish hair-like scales; legs with femora covered with white flattened scales becoming tan distally, also with long white hair-like scales predominately on ventral surface and becoming shorter distally; tibia, tarsi and pretarsi brownish-tan, covered with stout setae, narrow white flattened scales on sparsely clothed tibia and tarsis. Wings: forewing with costal and outer margins slightly curved, inner margin straight, outer margin pointing outward anteriorally giving wings a slghtly pointed look, stem $R_{4\ 5}$ longer than R_5, upper surface completely clothed with flattened dull-white scales in approximate vertical rows except as follows: black flattened scales occurring solidly on basal one-tenth of wing, on costal margin of wing as eight small vertical marks extending to cell, on apex in typical *Euchloe* manner with intermixed white scales from R_1 to M_3 at distal ends of veins, and at distal end of discal cell as patch about thirteen scale rows wide with about one hundred white scales intermixed, long grayish-white hair-like scales coinciding with basal patch of black scales, yellow-buff narrow flattened scales extending along costal margin from base to apex, fringes (along inner and outer margins) composed of long white hair-like scales, black hair-like scales on fringe at terminus of R_5, M_1, M_2, M_3, and Cu_1. Hindwing above with dull white scales as on forewing, black flattened scales on basal area of wing, extending outwardly further than on forewing, at stem of cubitus, and at terminus of all veins coinciding with long black hair-like scales on fringe; ventral surface of forewing with white scales as above, black scales as above on costal margin and outer margin, black patch at end of discal cell not as extensive as on upper surface and white scales absent, black scales absent at base of wing and

much less extensive on apical area, yellow-buff scales as on upper surface, sparsely distributed white hair-like scales occurring anterior to cubitus and extending to outer end of discal cell, flattened yellow scales occurring with black scales on apical area giving greenish appearance; lower surface of hindwing with flattened slightly dentate white scales in rough rows in between complex "green" marbled pattern produced by intermixing of flattened black and yellow scales, long hair-like scales, white on white areas and pale yellow over marbling extending from base of wing approximately to an imaginary line from distal end of anal margin to distal end of inner margin, a small patch of flattened black scales contiguous with marbling at Mu-Cu with one long black hair-like scale. Abdomen: dorsum clothed with flattened black scales intermixed with a few flattened white scales, white scales increasing and black scales decreasing ventrally until all white on sternum, long grayish hair-like scales on anterior half of abdomen and along entire length on sternum, white slightly spatulate scales sparsely covering posterior half of abdomen and densely covering posterior margin of segment eight and outer surface of valvae.

Female. — Forewing length, 22 mm. As in male except patch at end of discal cell of forewing about eighteen scale rows in width with about twenty white scales intermixed; hindwing above with scales yellow-cream in color; scales on lower surface of forewing largely buff in color, about fifty white scales in center of patch at end of FW discal cell ventrally.

Euchloe creusa (Doubleday)

Male. — Forewing length, 18 mm. Antennae brownish-tan, outer surface clothed with black and white scales, white predominating; hair-like scales on dorsal surface of thorax as in *E. ausonides* but denser, yellow flattened and long yellow hair-like scales on pleuron; legs with long black and white hair-like scales primarily on ventral surface of femora, white predominating; forewing with stem $R_{4\ 5}$ about equal in length to R_5, upper surface of forewing with eight black marks on costal margin, "Euchloe" mark at apex with white area above M_1 not as a well-defined circle, instead the effect is of a diagonal bar beginning between R_3 and R_4 and ending between M_2 and M_3; bar mark at distal end of cell about eight scale rows in width with about 35 white scales intermixed; flattened black scales extending into cell from basal area on dorsal surface of hindwing; white scales

on ventral surface of hindwing more iridescent than those of *E. ausonides;* marbling more extensive and irregular than that of other Nearctic species. Abdomen: flattened black scales on dorsal and pleural areas with only an occasional white scale; venter covered with a mixture of white and pale yellow flattened scales; long hair-like scales covering entire surface of abdomen, gray on dorsal and pleural areas, yellowish ventrally.

Female. — Forewing length, 17.8 mm. As in male except patch at end of discal cell on forewing about sixteen scale rows in width with about seven white scales intermixed; flattened black scales on upper surface of hindwing as in male but some present on all areas of wing; a small patch of about 30 black scales present on ldc; about 25 dull gray scales in center of patch at end of discal cell on ventral surface of forewing.

Euchloe olympia (Edwards)

Male. — Forewing length, 18.5 mm. Antennae: outer surface of shaft and most of club clothed with small white flattened scales; labial palpi about one and a half times as long as head, clothed with white elongate scales, about four times as long as wide, long white hair-like scales projecting downward and inward, a few long black hair-like scales intermixed on outer face; frons with prominent tuft of long white and black hair-like scales directed anterad slightly beyond tips of palpi, white mesially with some black scales laterally; pleuron covered with yellow sub-elliptic flattened scales and long yellow hair-like scales; legs with scaling as for *E. ausonides.* Wings: R_5 almost twice length of stem $R_{4\ 5}$, upper surface with white ground slightly more iridescent than that of *E. ausonides;* black maculation on apex reduced to three small patches, one just basal to R_3 bifurcation, one at distal end of M_3, and one composed of scattered black scales near $R_{4\ 5}$; four small vertical marks in C-Sc formed by small patches of black scales; patch at distal end of discal cell on dorsal surface of forewing about 13 scale rows in width with about five white scales intermixed; black scales not present in fringe; buff scales absent from costal area; hindwing with long black scales in fringe at termini of Rs and M_1; ventral surface of forewing with black scales as above patch at $R_{4\ 5}$ absent, flattened yellow scales occurring with black scales in two apical patches giving greenish appearance; patch at end of discal cell much less extensive than on dorsal surface with about 100 white scales in central portion; ventral surface of hind-

wing with marbling pattern strongly reduced. Abdomen: dorsal and pleural areas clothed with flattened black scales with a few white scales, venter clothed with white scales.

Female. — Forewing length, 19.2 mm. As in male except patch at end of discal cell on forewing about 14 scale rows in width with no white scales intermixed; about 50 white scales in central portion of patch at distal end of cell on ventral surface of forewing.

Euchloe hyantis (Edwards)

Male. — Forewing length, 17.5 mm. Outer surface of antennal shaft and club clothed with white and black scales, white predominating; labial palpi lacking black elongate scales as in *E. ausonides*, frons lacking long yellowish hair-like scales; patch of hair-like scales at lateral margin of vertex with white and black scales; a group of short pure white scales between eyes and base of antenna; on forewing stem $R_{4\ 5}$ much longer than R_5; patch at distal end of discal cell on dorsal surface of forewing about 13 scale rows in width with only two white scales intermixed; buff scales absent from costal margin; ventral surface of forewing with patch at distal end of cell about as extensive as on dorsal surface with no perceptibly lighter scales in center.

Female. — Forewing length, 18.1 mm. As in male except patch at distal end of cell on dorsal surface of forewing about 16 scale rows in width with no white scales intermixed; about 70 light gray scales in center of patch at end of FW discal cell ventrally.

ADDENDUM

After the manuscript for this paper was submitted for publication, the materal of this genus contained in the Canadian National Collection was examined. Since the material there included important distributional additions, the data for their material from Alaska and Canada are presented below. It should be noted that none of this information has been incorporated on the distribution maps.